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Perez

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(54) METHOD AND APPARATUS FOR INTERNET PROTOCOL (IP) LOGICAL WIRE SECURITY

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H04L 12/703 (2013.01)
H04L 12/751 (2013.01)

(52) **U.S. Cl.**
CPC ***H04L 45/28*** (2013.01); *H04L 45/02* (2013.01)

(58) **Field of Classification Search**
CPC G06F 11/00; G06F 11/10; G06F 15/173; H04M 1/66; H04M 11/04; H04L 12/56; H04L 12/26; H04L 29/06; H04W 24/04
USPC 370/225, 235, 245, 252, 254, 349, 389, 370/392, 395.1, 397, 401, 419; 455/411, 455/423; 709/207–224
See application file for complete search history.

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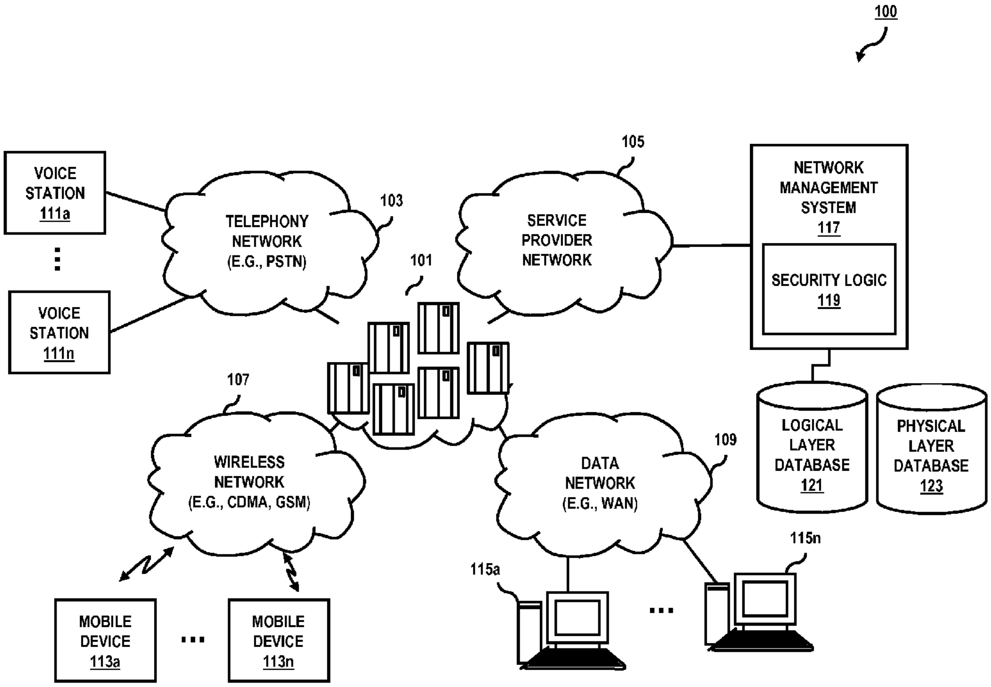
Assistant Examiner — Wali Butt

(57) **ABSTRACT**

A method and apparatus for improved approaches for detection of exploits and drift in a network is described. The method includes: determining, by a processor, a logical configuration of a network comprising a plurality of links connecting a plurality of nodes; determining, by the processor, a physical path corresponding to one of the links, the physical path including a plurality of switches of the network, wherein the processor is configured to determine whether data sent on one of the nodes to another one of the nodes by the one link is received at the other node; receiving an error detection value computed by one of the switches; and determining, by the processor, whether the error detection value corresponds with a value inaccessible to the one switch.

22 Claims, 9 Drawing Sheets



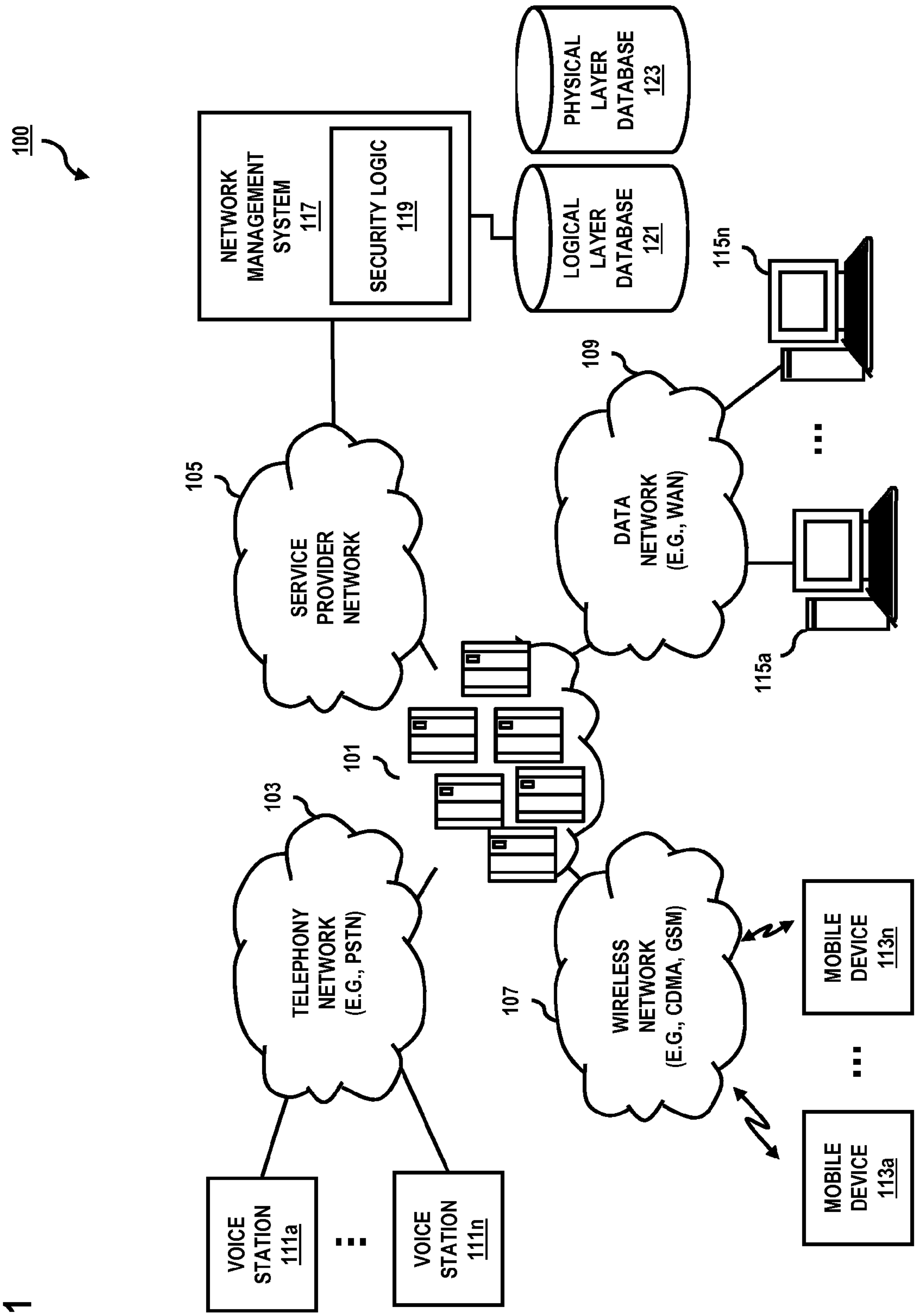

100
NETWORK MANAGEMENT SYSTEM 117
SECURITY LOGIC 119
LOGICAL LAYER DATABASE 121
PHYSICAL LAYER DATABASE 123
105
SERVICE PROVIDER NETWORK
109
DATA NETWORK (E.G., WAN)
115n
115a
101
103
TELEPHONY NETWORK (E.G., PSTN)
107
WIRELESS NETWORK (E.G., CDMA, GSM)
MOBILE DEVICE 113n
MOBILE DEVICE 113a
VOICE STATION 111a
VOICE STATION 111n

FIG. 1

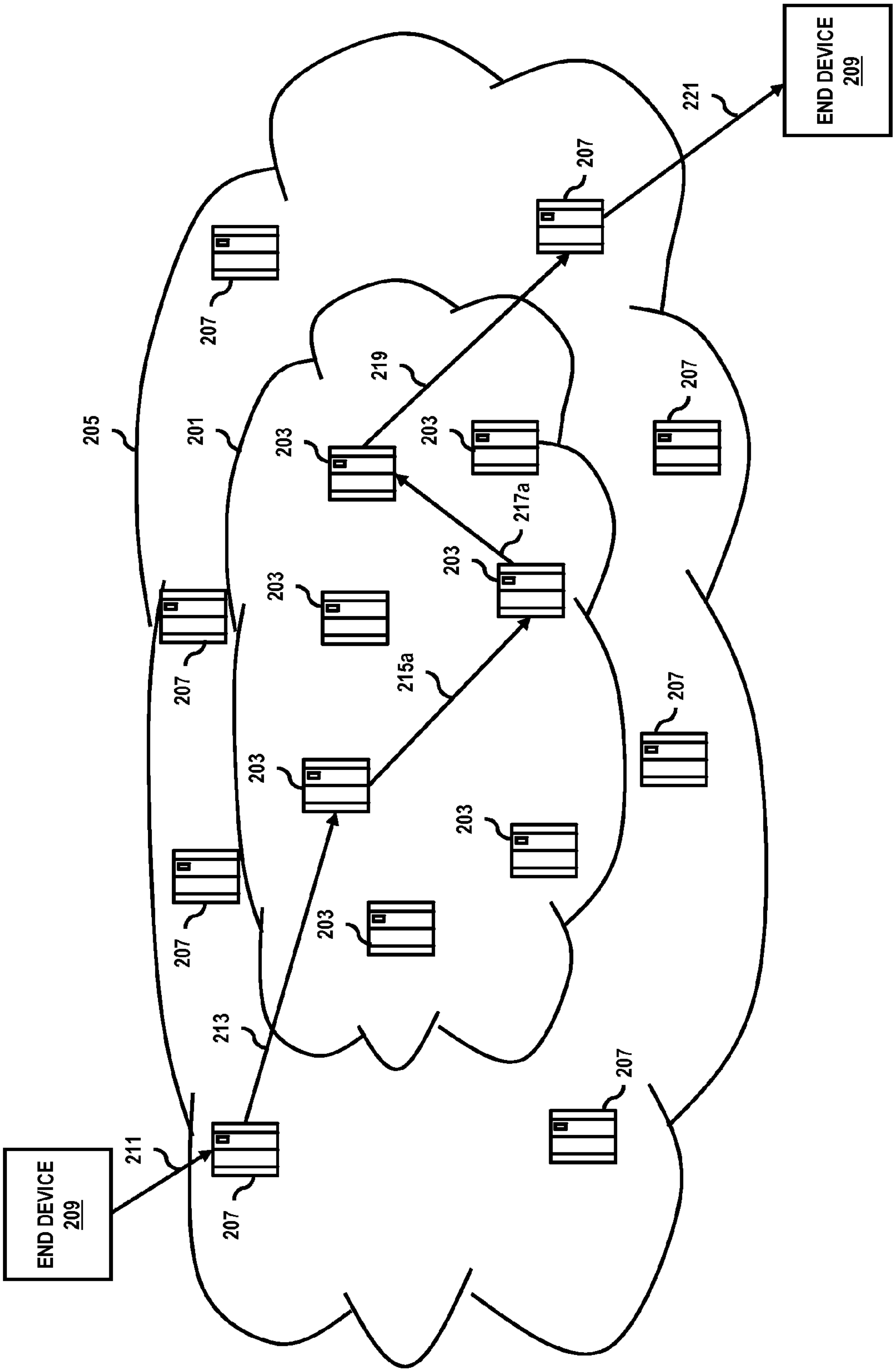

END DEVICE
209
211
207
213
207
207
203
203
215a
203
203
217a
203
203
219
201
205
207
207
207
207
207
221
END DEVICE
209
207

FIG. 2A

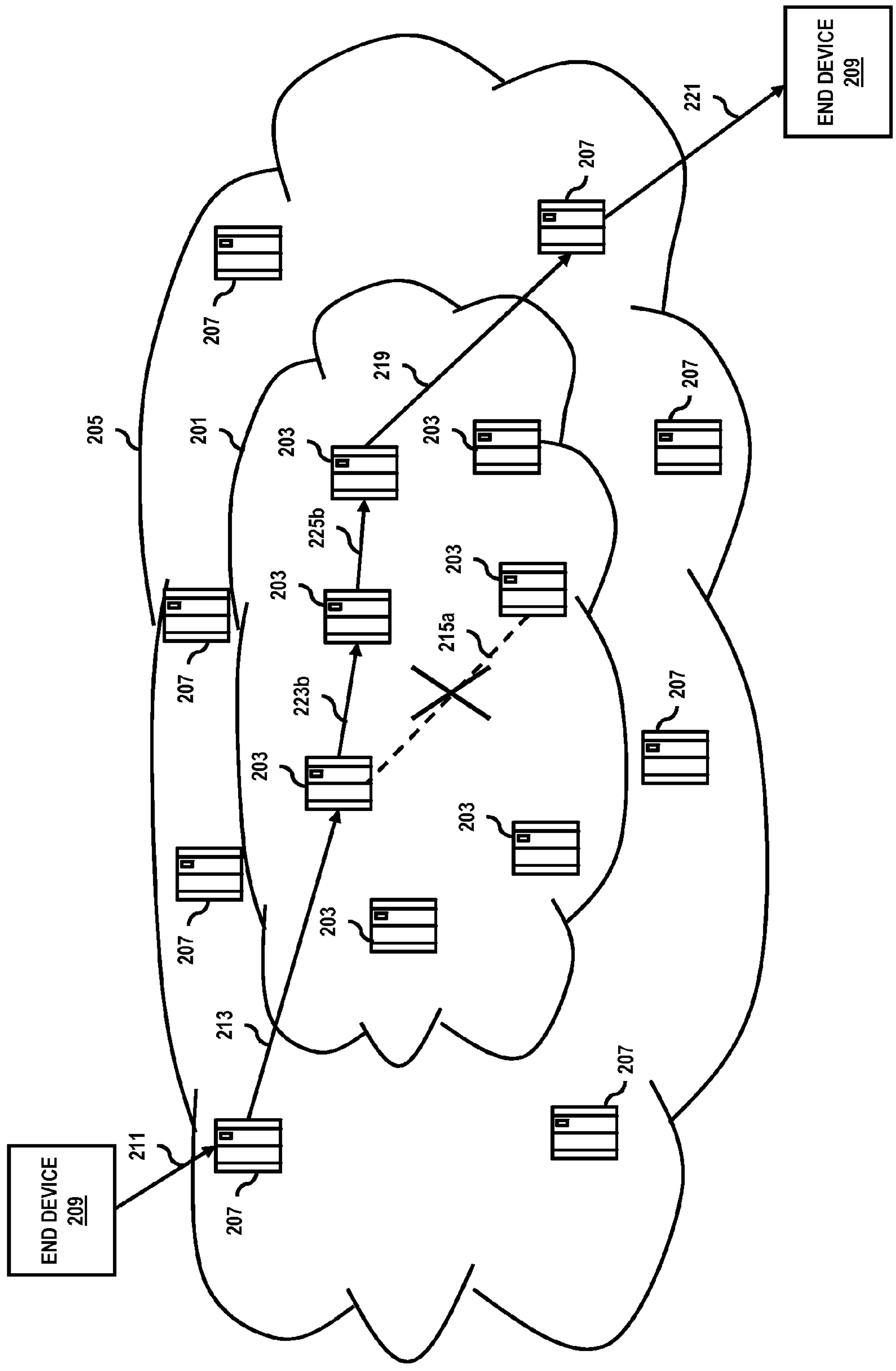

END DEVICE
209
211
207
213
205
201
207
207
207
203
203
203
203
203
203
223b
225b
215a
219
207
207
207
207
221
END DEVICE
209

FIG. 2B

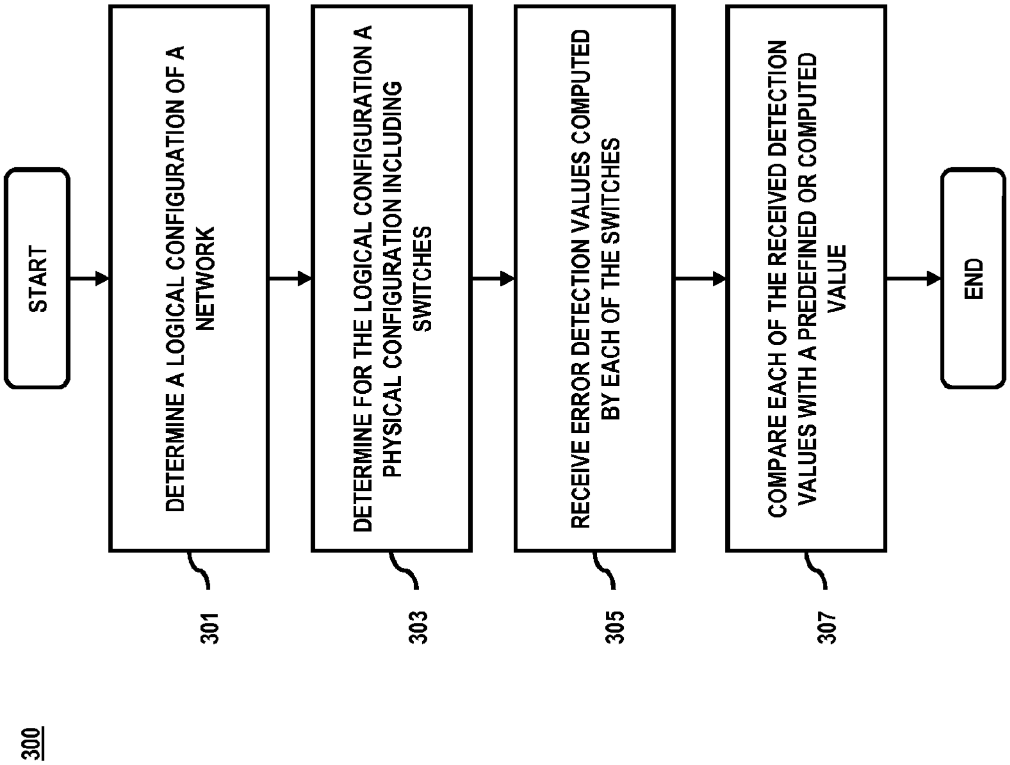
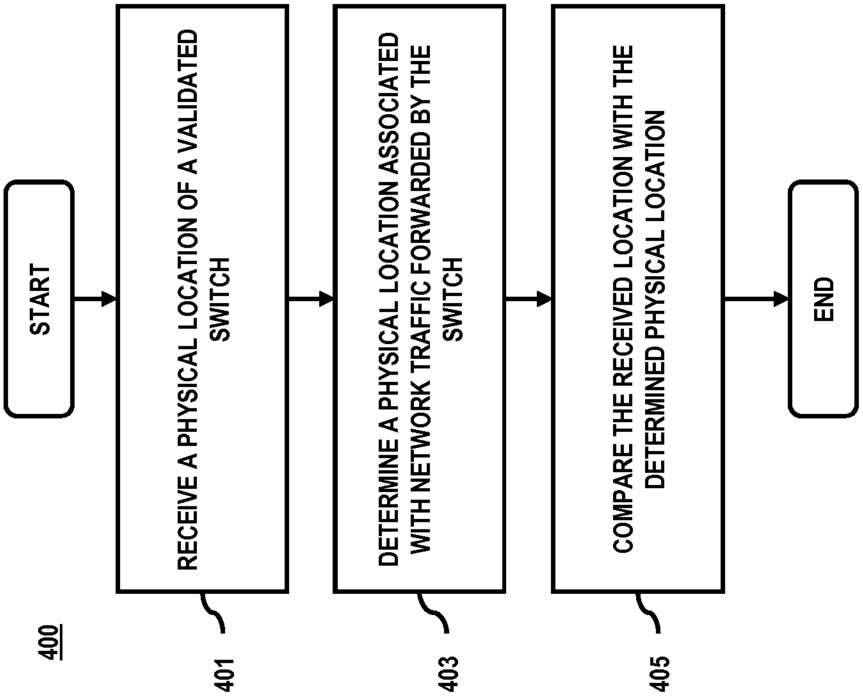

300
START
DETERMINE A LOGICAL CONFIGURATION OF A NETWORK
301
DETERMINE FOR THE LOGICAL CONFIGURATION A PHYSICAL CONFIGURATION INCLUDING SWITCHES
303
RECEIVE ERROR DETECTION VALUES COMPUTED BY EACH OF THE SWITCHES
305
COMPARE EACH OF THE RECEIVED DETECTION VALUES WITH A PREDEFINED OR COMPUTED VALUE
307
END

FIG. 3

FIG. 4


400
START
RECEIVE A PHYSICAL LOCATION OF A VALIDATED SWITCH
401
DETERMINE A PHYSICAL LOCATION ASSOCIATED WITH NETWORK TRAFFIC FORWARDED BY THE SWITCH
403
COMPARE THE RECEIVED LOCATION WITH THE DETERMINED PHYSICAL LOCATION
405
END

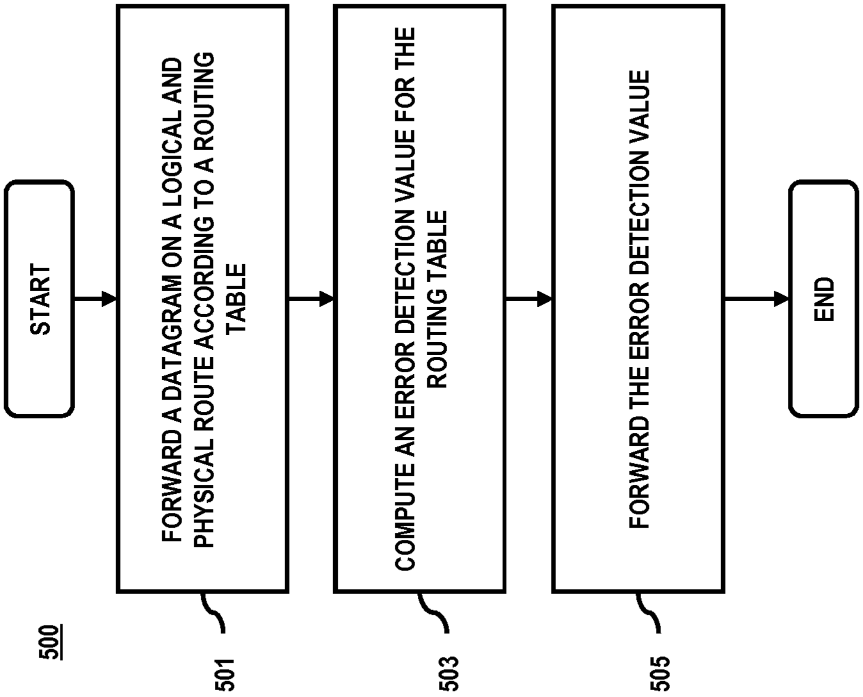

500
START
FORWARD A DATAGRAM ON A LOGICAL AND PHYSICAL ROUTE ACCORDING TO A ROUTING TABLE
501
COMPUTE AN ERROR DETECTION VALUE FOR THE ROUTING TABLE
503
FORWARD THE ERROR DETECTION VALUE
505
END

FIG. 5

FIG. 6

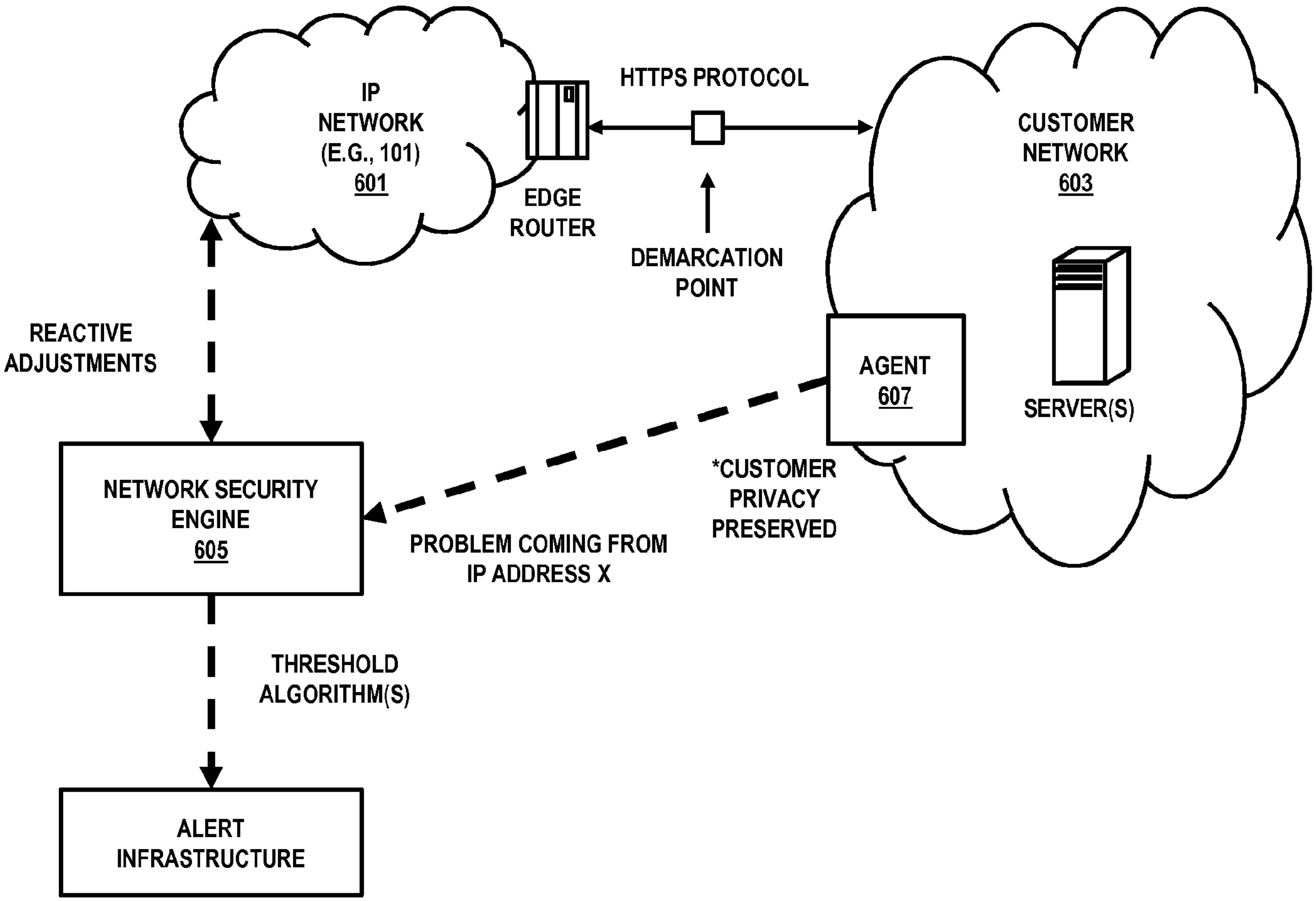

IP
NETWORK
(E.G., 101)
601
EDGE
ROUTER
HTTPS PROTOCOL
DEMARCATION
POINT
CUSTOMER
NETWORK
603
AGENT
607
SERVER(S)
*CUSTOMER
PRIVACY
PRESERVED
REACTIVE
ADJUSTMENTS
NETWORK SECURITY
ENGINE
605
PROBLEM COMING FROM
IP ADDRESS X
THRESHOLD
ALGORITHM(S)
ALERT
INFRASTRUCTURE

FIG. 7

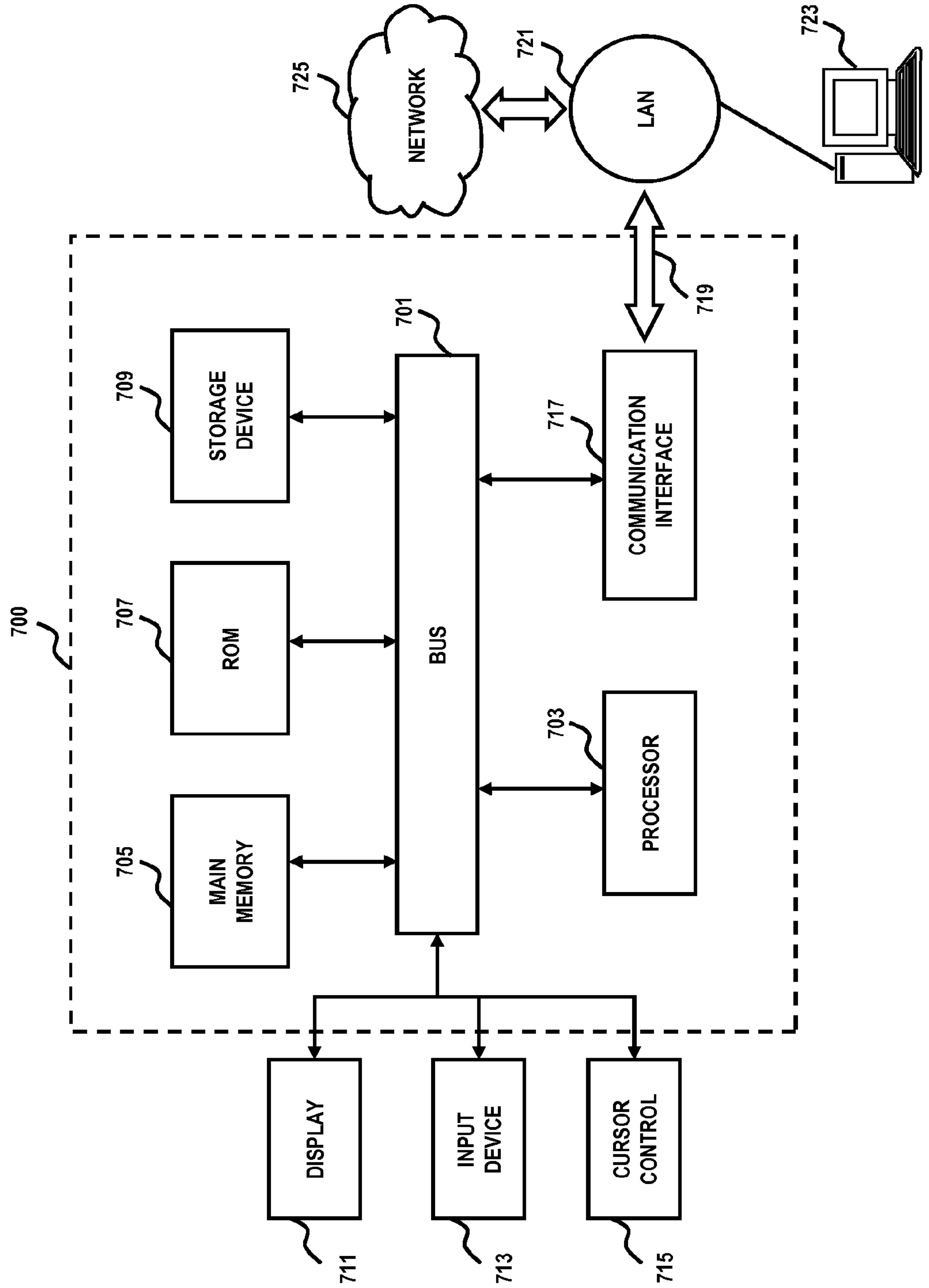
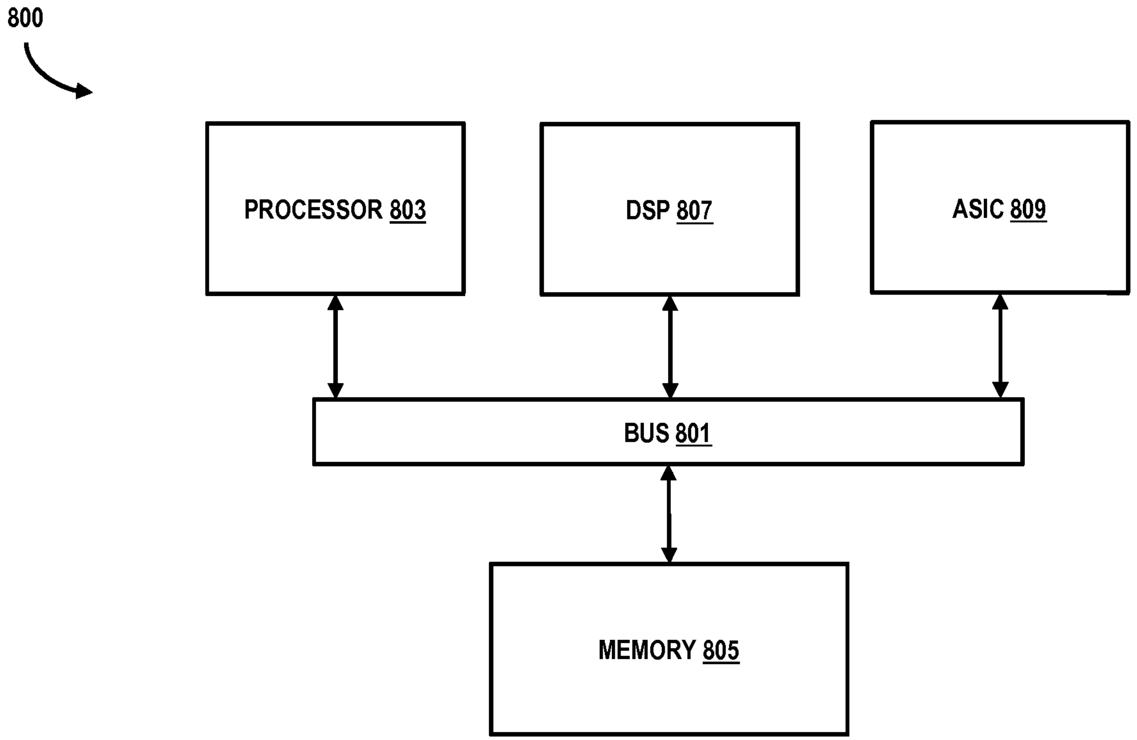

700
705
MAIN MEMORY
707
ROM
709
STORAGE DEVICE
701
BUS
703
PROCESSOR
717
COMMUNICATION INTERFACE
719
721
LAN
725
NETWORK
723
711
DISPLAY
713
INPUT DEVICE
715
CURSOR CONTROL

FIG. 8



METHOD AND APPARATUS FOR INTERNET PROTOCOL (IP) LOGICAL WIRE SECURITY

BACKGROUND INFORMATION

Networking technologies using IP technologies offer users the flexibility to handle video, data, and voice. Additionally, IP technologies operate at a reduced cost than other telecommunication technologies, for instance, signaling system v7 (SS7). However, IP technologies, such as voice over the internet protocol (VOIP), session initiation protocol (SIP), session description protocol (SDP), and the like, may be exploited. For instance, the automatic number indicator (ANI), also known as "caller ID" of a calling party may be falsified using an ANI exploit. Furthermore, networks using such IP technologies may experience a drift of logical and physical configurations, for example, due to modifications to the physical network without updating a system tracking changes to the network. Performing a line by line interrogation of physical tables and logical route tables to ensure proper configuration requires a significant computation effort and telemetry bandwidth impacting network performance, and thus is not feasible in large scale systems.

Therefore, there is a need for approaches to detect exploits and a drift of a large scale network to provide better security in networks utilizing IP or equivalent technologies.

BRIEF DESCRIPTION OF THE DRAWINGS

Various exemplary embodiments are illustrated by way of example, and not by way of limitation, in the figures of the accompanying drawings in which like reference numerals refer to similar elements and in which:

FIG. **1** is a diagram of a communication system capable of detecting exploits and drift of a network, according to various embodiments;

FIGS. **2**A and **2**B are diagrams of the components of an IP network, according to exemplary embodiments;

FIGS. **3** and **4** are flowcharts of processes for detecting exploits and drift in a network, according to one embodiment;

FIG. **5** is a flowchart of a process for validating a switch in a network, according to one embodiment;

FIG. **6** is an illustration of one embodiment of detecting exploits and drift in private network traffic using a remote agent;

FIG. **7** is a diagram of a computer system that can be used to implement various exemplary embodiments; and

FIG. **8** is a diagram of a chip set that can be used to implement various exemplary embodiments.

DESCRIPTION OF THE PREFERRED EMBODIMENT

A preferred method and system for detecting exploits and drift in a network is described. In the following description, for the purposes of explanation, numerous specific details are set forth in order to provide a thorough understanding of the preferred embodiments of the invention. It is apparent, however, that the preferred embodiments may be practiced without these specific details or with an equivalent arrangement. In other instances, well-known structures and devices are shown in block diagram form in order to avoid unnecessarily obscuring the preferred embodiments of the invention.

FIG. **1** is a diagram of a communication system capable of detecting exploits and drift of a network, according to various embodiments. For illustrative purposes, system **100** is described with respect to an IP network **101** to connect networks. In this example, the IP network **101** is configured to establish network connectivity between a telephony network **103**, a service provider network **105**, a wireless network **107**, and a data network **109**. For example, the IP network **101** may be a meshed multi-path data networking cloud core portion using backbone fiber transmission for core switch/routers and include, for instance, 3G/4G wireless towers and edge routers along an edge of the cloud. As shown, telephony network **103** uses time division multiplexed (TDM) communications for SS7 with a physical wire layout. Telephony network **103** is configured to allow connectivity of a voice station **111***a* (e.g., plain old telephone service (POTS) device) to voice station **111***n* connected to the telephony network **103**, another voice station (not shown) connected to another telephony network (not shown) connected to the IP network **101**, or another device of yet another network connected by IP network **101**, such as mobile device **113***a* of wireless network **107** and computing device **115** (e.g., laptop, desktop, web appliance, netbook, etc.) of data network **109**. The service provider network **105** may include a network management system **117** (e.g., a Back office) having security logic **119** and access to a logical layer database **121** and a physical layer database **123** corresponding to the IP network **101**. As such, the network management system **117** monitors equipment (e.g., switches/routers) of the IP network **101** to improve security and reliability of the IP network **101**. In some embodiments, the network management system **117** is Sarbanes Oxley (SOX) compliant, and thus changes relative to IP network **101** are tracked and non-repudiated. The network management system **117** may be utilized in a telecommunication network management (TNM) process.

As mentioned, detecting exploits and drift in a network involves significant computational resources and telemetry bandwidth. As such, continuous stateful detection of networks (e.g., IP network **101**) is not feasible, especially for large scale networks. Utilizing frequency trending algorithms allows a stateful detection to be dynamically performed on a portion of a network (e.g., a logical wire). However, information from a switch/router fabric used by such trending algorithms may be remotely exploited or have a modified configuration. As such, trending algorithms may not initiate a dynamic stateful detection when an exploit or modification impacts a switch/router fabric of a network and thus, the exploits and/or modifications may remain undetected.

To address this issue, the system **100** of FIG. **1** introduces the capability to verify information from a switch/router fabric enabling an enhanced detection of exploits and/or modifications in a large scale network. By way of example, each switch of the IP network **101** computes an error detection value (e.g., checksum) for data stored in a corresponding routing table and configuration of the switch, and sends the error detection value (e.g., a binary value) to network management system **117**. The network management system **117** then verifies (and validates) a routing table of a switch when a received error detection value is identical to a predefined value. As such, the use of error detection values to verify switches/routers enables a switch/routing fabric of a network to be verified without a continuous stateful inspection. Furthermore, when a received error detection value does not match the corresponding predefined value (or value computed by a network management system), auditing of a switch/router, logical/physical route, and/or portion of the IP network **101** may be initiated to determine a cause for the mismatch. As such, computation and telemetry resources of the IP network **101** may be preserved since only a portion of the IP network **101** is audited rather than the entire network. Further, network management system **117** may be configured to compare a physical path of network traffic within IP network **101** to a physical path indicated by the network traffic. As such, when the physical paths are not matched the network management system **117** may be configured to restrict and/or initiate a dynamic stateful inspection of the logical and physical routes of the IP network **101**.

As used herein, exploits of a network include, for example, a modification of the open systems interconnection (OSI) model layers 3-7 to spoof an IP address of an IP packet and force it into a logical cloud (e.g., IP network **101**) from an edge so that it may be routed to another IP destination. In another example, a MAC hex address of a device is altered by modifying a firmware or driver of a network interface card (NIC). In yet another example, an ANI of network traffic is modified (e.g., ANI spoofing) in the session initiation protocol (SIP) application layer protocol running over a TCP or UDP on top of the IP protocol. Additional exploits of the layers 3-7 include protocols such as, for example, simple network management protocol (SNMP), TELNET, and simple mail transfer protocol (SMTP).

Although depicted as separate entities, the networks **101-109** may be completely or partially contained within one another, or may embody one or more of the aforementioned infrastructures. For instance, the service provider network **105** may embody circuit-switched and/or packet-switched networks that include facilities to provide for transport of circuit-switched and/or packet-based communications. It is further contemplated that the networks **101-109** may include components and facilities to provide for signaling and/or bearer communications between the various components or facilities of the system **100**. In this manner, the networks **101-109** may embody or include portions of a SS7 network, Internet protocol multimedia subsystem (IMS), or other suitable infrastructure to support control and signaling functions.

The networks **101-109** may be any suitable wireline and/or wireless network, and be managed by one or more service providers. For example, the data network **109** may be any local area network (LAN), metropolitan area network (MAN), wide area network (WAN), the Internet, or any other suitable packet-switched network, such as a commercially owned, proprietary packet-switched network, such as a proprietary cable or fiber-optic network. For example, computing device **115** may be any suitable computing device, such as a VoIP phone, skinny client control protocol (SCCP) phone, session initiation protocol (SIP) phone, IP phone, personal computer, softphone, workstation, terminal, server, etc. The telephony network **103** may include a circuit-switched network, such as the public switched telephone network (PSTN), an integrated services digital network (ISDN), a private branch exchange (PBX), or other like network. For instance, voice station **111** may be any suitable POTS device, facsimile machine, etc. Meanwhile, the wireless network **107** may employ various technologies including, for example, code division multiple access (CDMA), long term evolution (LTE), enhanced data rates for global evolution (EDGE), general packet radio service (GPRS), mobile ad hoc network (MANET), global system for mobile communications (GSM), Internet protocol multimedia subsystem (IMS), universal mobile telecommunications system (UMTS), etc., as well as any other suitable wireless medium, e.g., microwave access (WiMAX), wireless fidelity (WiFi), satellite, and the like.

As used herein, IP network **101** is configured to utilize public IP routing, for example, utilizing publicly routed IP subnet address space provided by the internet assigned number authority (LANA). As such, end users may acquire a public address dynamically (or statically) from an internet service provider (ISP), for instance, service provider network **105**. Additionally, the IP network **101** may comprise a plurality of independently monitored and controlled IP networks. Further, such a plurality of IP networks can initiate the processes illustrated in FIGS. **1** though **6** dynamically to determine end-to-end logical and physical connections across IP network **101**.

As used herein, mobile devices **113** may be any type of mobile terminal including a mobile handset, mobile station, mobile unit, multimedia computer, multimedia tablet, communicator, netbook, Personal Digital Assistants (PDAs), smartphone, media receiver, etc. It is also contemplated that the mobile devices **113** may support any type of interface for supporting the presentment or exchange of data. In addition, mobile devices **113** may facilitate various input means for receiving and generating information, including touch screen capability, keyboard and keypad data entry, voice-based input mechanisms, accelerometer (e.g., shaking the mobile device **113**), and the like. Any known and future implementations of mobile devices **113** are applicable. It is noted that, in certain embodiments, the mobile devices **113** may be configured to transmit information (e.g., audio signals, words, address, etc.) using a variety of technologies—e.g., NFC, BLUETOOTH, infrared, etc. Also, connectivity may be provided via a wireless local area network (LAN). By way of example, a group of mobile devices **113** may be configured to a common LAN so that each device can be uniquely identified via any suitable network addressing scheme. For example, the LAN may utilize the dynamic host configuration protocol (DHCP) to dynamically assign "private" DHCP IP addresses to each mobile device **113**, e.g., IP addresses that are accessible to devices connected to the service provider network **105** as facilitated via a router. Some mobile device **113** may be configured to utilize serial numbers for radio communication authentication to reduce spoofing of the device, and to improve accuracy of monitoring statistical trending behavior of the network.

In certain embodiments, network management system **117** may include or have access to logical and physical layer configuration information of the IP network **101** stored in logical layer database **121**, and physical layer database **123**, respectively. Physical layer configuration may include networking hardware, such as physical links connecting switches and/or routers, properties such as frequencies, modulation schemes, character encoding, transmission, reception and decoding methods, physical link distances, error correction schemes, physical network topology (e.g., bus, ring, mesh, star), protocols (e.g., DSL, ISDN, SONET, BLUETOOTH, etc.), and the like. Logical layer configuration may include nodes and pathways representing data transfers between points of the physical layer configuration. Additionally, multiple network management systems (e.g., **117**) may access a single or multiple logical layer databases (e.g., **121**) and/or physical layer databases (e.g., **123**). The physical and/or logical configurations stored in the databases **121** and **123**, respectively, may be real time and track changes for acceptance (e.g., non-repudiated) by a Back Office. The network management system **117** may be configured to access and store information simultaneously from switches and routes of IP network **101** into one or more logs (e.g., databases **121** and/or **123**) to facilitate a detection (e.g., dynamic/continuous stateful inspection) of exploits and/or drift of the IP network **101**.

While specific reference will be made thereto, it is contemplated that the system **100** may embody many forms and include multiple and/or alternative components and facilities.

By way of example, FIGS. **2**A and **2**B are diagrams of the components of an IP network, according to exemplary embodiments. As illustrated in FIGS. **2**A and **2**B, the IP network includes a core network **201** with core routers **203** surrounded by an edge network **205** with edge routers **207**. End devices **209** exchange network traffic by each connecting to edge routers **207** which then forward the network traffic using core routers **203**. In some embodiments, the network traffic of the core network **201** and edge network **205** is monitored by a network management system (e.g., **117**). Adverting to FIG. **2**A, network data is exchanged between end devices **209** via a first physical path **211** between the end device **209** and edge router **207**, a second physical path **213** between the edge router **207** and core router **203**, third and fourth physical paths **215***a* and **217***a*, respectively, between core routers **203**, a fifth physical path **219** between core router **203** and edge router **207**, and a sixth physical path **221** between edge router **207** and end device **209**. Adverting to FIG. **2**B, physical path **215***a* is unavailable. As such, routing logic forwards the network traffic similar to FIG. **2**A, except network traffic within the IP network **101** is transported via first and second alternate physical paths **223***b* and **225***b* instead of the third and fourth physical paths **215***a* and **217***a*, respectively. The routing logic is stored in one or more of the core routers **203** and/or a network management system (e.g., **117**). For example, the network management system may receive an indication from one or more of the core routers **203** that the physical path **215***a* is unavailable (e.g., latency exceeding a predefined threshold) and send updated routing tables to the core routers **203** indicating a new logical path corresponding to the alternate physical paths **223***b* and **225***b*. In another example, one or more of the core routers **203** detect that a logical path utilizing the physical path **215***a* is unavailable (e.g., received no confirmation that a datagram was received within a time period) and each routing table of the core routers **203** are updated to indicate a new logical path utilizing the alternate physical paths **223***b* and **225***b*.

FIG. **3** is a flowchart of a process for detecting exploits and drift in a network, according to one embodiment. For illustrative purpose, process **300** is described with respect to the systems of FIGS. **1**, **2**A, and **2**B. It is noted that the steps of process **300** may be performed in any suitable order, as well as combined or separated in any suitable manner.

In step **301**, the network management system **117** determines a logical configuration of IP network **101**. For instance, the network management system **117** receives a message from a core router **203** indicating a packets transmitted on a first logical route fail to be received, and the network management system **117** sends updated routing tables to core routers **203** indicating an alternative logical route and updates the logical layer database **121** accordingly. In another example, the network management system **117** accesses logical layer database **121** to determine a stored logical configuration. In step **303**, the network management system **117** determines a physical configuration for the logical configuration of IP network **101**. For instance, the network management system **117**, determines network traffic transported by physical path **215***a* has a bit error rate (BER) exceeding the predefined value, and the network management system **117** sends updated routing tables to core routers **203** indicating logical routes utilizing physical paths **223***b* and **225***b* rather than physical paths **215***a* and **217***a* and updates the physical layer database **123** accordingly. Alternatively, the network management system **117** may receive a message from one or more routers (e.g., **203** and/or **207**) indicating a first logical route is unavailable and the network management system **117** sends updated routing tables to core routers **203** indicating routes utilizing physical paths **223***b* and **225***b* rather than physical paths **215***a* and **217***a* and updates the physical layer database **123** accordingly. In yet another example, the network management system **117** accesses physical layer database **123** to determine a stored physical configuration.

Next, the network management system **117** receives, as in step **305**, an error detection value from each of the core routers **203** and edge routers **205**. For example, each of the routers **203** and **205** receives an algorithm distributed by the network management system **117**. Next, each of the routers **203** and **205** executes the algorithm to compute a bitvalue using a current device configuration (e.g., firmware version, device model number, MAC address, etc.) and/or a current datastore (e.g., file size, routing table values, etc.). The bitvalue is then received via the networks **101**-**109** by the network management system **117**. In some embodiments, the bitvalue is transmitted by an encrypted communication, such as SSL, and/or is isolated to a module or virtual machine (VM) with only secure access. As such, a visibility of the bitvalues may be restricted to a particular system(s) and/or administration community. Furthermore, the VM may have segregated resources utilizing a private network (e.g., customer network **603**).

The network management system **117** then compares, as in step **307**, each of the received detection values with predefined and/or computed values. For instance, the network management system **117** computes a bitvalue for each of the routers **203** and **205** according to configurations stored in databases **121** and **123** (and another database) and compares the computed bitvalues to the corresponding received bitvalue. In another example, the network management system **117** compares the received bitvalues with a log (not shown) containing predetermined bitvalues.

The network management system **117** may initiate a cross enterprise customer network security trending based on the comparison. For example, the network management system **117** may include VERIZON WEBZ using a spider subsystem analysis of network data utilizing data from routers **203** and **205** when the (computed) bitvalues match to the received bitvalues. As such, the network management system **117** can determine, in real time, whether a particular IP address has been involved in other recent specific activity and, for instance, initiate an ACL block on the particular IP address for a period of time. Furthermore, the comparison allows the network management system **117** to tie logical information to physical information enabling enhanced investigations of a network (e.g., **101**). For example, logical and physical information from routers enables an identification of an origin of malicious encrypted IP traffic. In another example, the logical and physical information enables identification of a regional ingress location of painted targets (e.g., tracing synthetic information across multiple accounts). Such investigations may be in real time, using a trending database by a batch spider subsystem, or ad hoc.

For illustrative purpose, process **400** of FIG. **4** is described with respect to the systems of FIGS. **1**, **2**A, and **2**B. It is noted that the steps of process **400** may be performed in any suitable order, as well as combined or separated in any suitable manner.

In step **401**, the network management system **117** receives a physical location of a validated switch. For instance, the network management system **117** designates the routers **203** and **205** as validated when the comparison in step **305** indicates the received and predefined values are identical. The network management system **117** then receives messages from each of the routers **203** and **205** indicating a corresponding geolocation of each of the routers **203** and **205**.

In step **403**, the network management system **117** determines a physical location associated with network traffic forwarded by the switch. In one embodiment, the network management system **117** determines the physical location based on information contained in network traffic (e.g., datagram). For example, the network management system **117** determines an ANI for a datagram and determines a geolocation for the ANI in a known number administration and portability list maintained by the number portability administration center (NPAC). In another example, the network management system **117** determines a physical location for a datagram based on a geolocation of an edge router **205** corresponding to an endpoint of a source and/or destination IP address for the datagram. Additionally, when a datagram indicates a location outside of a network, a geolocation of an edge router (e.g., **207**) may be used as a physical location of the datagram. For example, each edge router **207** maintains a log indicating destination addresses of end devices (e.g., **209**) connected to the IP network (e.g., **101**, **205**) by the edge router **207**. In another example, the network management system **117** dynamically associates a geolocation of an edge router **207** connecting a destination address to the IP network with the destination address. In yet another example, the network management system **117** maintains a log (not illustrated) indicating destination addresses of each end device (e.g., **209**) connected to the IP network by the edge routers **207**.

In one embodiment, the network management system **117** determines one or more physical locations associated with network traffic based on a MAC addresses associated with network traffic. That is, the network management system **117** determines a type of endpoint device of the network traffic based on a MAC address associated with the endpoint device (e.g., mobile device **113**, computing device **115**, etc.) and associates known geolocations for the type of endpoint device with the network traffic. For example, a MAC address of network traffic may indicate an endpoint device of the network traffic is a gaming device associated with specific server locations for the gaming device utilizing certain protocols (e.g., TCP/IP, IPV4, etc). As such, the network management system **117** can determine typical geolocations (and protocols) associated with network traffic to/from the gaming device based on a MAC address of the network traffic. It is contemplated that processes improving an accuracy of MAC address of end devices may be utilized with the embodiments illustrated in FIGS. **1** through **6**, for instance, use of a signed MAC incorporated in a fabrication process of end devices (e.g., **209**) that cannot be modified by Berkeley (BSD) socked coding.

Next, in step **405**, network management system **117** compares the received location with the determined physical location. For example, a geolocation associated with an ANI for a datagram is compared with the geolocation of each of the routers **203** and **205** forwarding the datagram. In another example, a geolocation associated with a source (or destination) IP address for a datagram is compared with the geolocation of each of the routers **203** and **205** forwarding the datagram. In yet another example, typical server locations associated with a MAC address are compared with the geolocations of each of the routers **203** and **205** forwarding the datagram. As such, network traffic (e.g., datagrams) purporting to be associated with a geolocation can be verified using geolocations of routers (e.g., **203** and **205**) forwarding the network traffic. Furthermore, a confidence of geolocations indicated by the switches/routers can be enhanced by utilizing the steps illustrated in FIGS. **3** and **5** to verify and validate a configuration of the switches/routers.

FIG. **5** is a flowchart of a process for validating a switch in a network, according to one embodiment. For illustrative purpose, process **500** is described with respect to the systems of FIGS. **1**, **2A**, and **2B**. It is noted that the steps of process **500** may be performed in any suitable order, as well as combined or separated in any suitable manner.

In step **501**, a router (e.g., router **203** or **205**) forwards a datagram on a logical and physical route according to a routing table. For example, the a first core router **203** receives a datagram from a second core router **203** and forwards the datagram to a third core router **203** by matching a destination address of the datagram with a route stored in a routing table for the first router **203**. In some embodiments the routing table is selected and tracked by network management system **117** to conform to security logic **119** based on configuration information stored in logical and physical layer databases **121** and **123**, respectively. Next, in step **503**, the router computes an error detection value for the routing table and forwards, as in step **505**, the error detection value. For instance, the router executes a checksum algorithm on a routing table stored in the router and on a firmware of the router and transmits the checksum to the network management system **117**. In some embodiments, the checksum algorithm is included in a firmware and/or read-only memory (ROM) of the router. Additionally, the checksum algorithm may be computed by a trusted CPU designated to monitor another CPU configured to perform normal processes of the router.

FIG. **6** is an illustration of one embodiment of detecting exploits in private network traffic using a remote agent. As shown, an IP network **601** (e.g., **101**) exchanges encrypted network traffic (e.g., HTTPS, SSL) with a customer network **603** (e.g., data network **109**) via a virtual private network (VPN). Additionally, customer network **603** may be regulated by government regulations (e.g., HIPAA) and affiliated with electronic commerce (e.g., SET financial transactions). As such, a network security engine **605** (e.g., **117**) is unable to monitor network traffic characteristics, for instance, an ANI of network traffic and maintain the privacy of customer network **603**. However, a remote agent **607** configured to monitor network traffic within the customer network **603** in real time can alert network security engine **605** of abnormal behavior (e.g., irregular traffic flows, rouge traffic flows, etc.) while maintaining the privacy of customer network **603**. For instance, remote agent **607** may be configured with VERIZON WEBZ to statistically store and trend communication anomalies and notify network security engine **605** of alerts in generic terms (e.g., critical, major, minor, etc.) to suite customer network **603** via a public (or private) network using an encrypted VPN. In another example, VERIZON WEBZ notifies network security engine **605** of an IP address of communication origin and time of the event along with preconfigured information (e.g., IP gateways involved with the event). In yet another example, the remote agent **607** constructs internal notifications for suspicious user behavior (e.g., login failure, extended session, restricted access, etc.)

Further, the remote agent **607** may be configured to perform the method described with respect to FIG. **5** to enable verification (and validation) of a configuration of the remote agent **607**. For instance, the remote agent **607** may compute an error detection value according to a checksum algorithm transmitted by network security engine **605** (or stored in a ROM in the remote agent **607**) that is computed based on a firmware version, operating system, and a file size, of the remote agent **607** and send the resulting binary values to the network security engine **605**. As such, the remote agent **607** may monitor the customer network **603** and be verified by the IP network **601** while maintaining the privacy of customer network **603**. Although remote agent **607** is shown as part of customer network **603**, the remote agent **607** may be within of a service provider network (e.g., **105**), or even a cloud based (e.g., IP network **601**). Remote agent **607** may be an application configured to support multiple types of operating systems (OS), for example, VERIZON WEBZ utilizing a POSIX complicate agent.

The processes described herein for detecting exploits and drift in a network may be implemented via software, hardware (e.g., general processor, Digital Signal Processing (DSP) chip, an Application Specific Integrated Circuit (ASIC), Field Programmable Gate Arrays (FPGAs), etc.), firmware or a combination thereof. Such exemplary hardware for performing the described functions is detailed below.

FIG. **7** is a diagram of a computer system that can be used to implement various exemplary embodiments. The computer system **700** includes a bus **701** or other communication mechanism for communicating information and one or more processors (of which one is shown) **703** coupled to the bus **701** for processing information. The computer system **700** also includes main memory **705**, such as a random access memory (RAM) or other dynamic storage device, coupled to the bus **701** for storing information and instructions to be executed by the processor **703**. Main memory **705** can also be used for storing temporary variables or other intermediate information during execution of instructions by the processor **703**. The computer system **700** may further include a read only memory (ROM) **707** or other static storage device coupled to the bus **701** for storing static information and instructions for the processor **703**. A storage device **709**, such as a magnetic disk, flash storage, or optical disk, is coupled to the bus **701** for persistently storing information and instructions.

The computer system **700** may be coupled via the bus **701** to a display **711**, such as a cathode ray tube (CRT), liquid crystal display, active matrix display, or plasma display, for displaying information to a computer user. Additional output mechanisms may include haptics, audio, video, etc. An input device **713**, such as a keyboard including alphanumeric and other keys, is coupled to the bus **701** for communicating information and command selections to the processor **703**. Another type of user input device is a cursor control **715**, such as a mouse, a trackball, touch screen, or cursor direction keys, for communicating direction information and command selections to the processor **703** and for adjusting cursor movement on the display **711**.

According to an embodiment of the invention, the processes described herein are performed by the computer system **700**, in response to the processor **703** executing an arrangement of instructions contained in main memory **705**. Such instructions can be read into main memory **705** from another computer-readable medium, such as the storage device **709**. Execution of the arrangement of instructions contained in main memory **705** causes the processor **703** to perform the process steps described herein. One or more processors in a multi-processing arrangement may also be employed to execute the instructions contained in main memory **705**. In alternative embodiments, hard-wired circuitry may be used in place of or in combination with software instructions to implement the embodiment of the invention. Thus, embodiments of the invention are not limited to any specific combination of hardware circuitry and software.

The computer system **700** also includes a communication interface **717** coupled to bus **701**. The communication interface **717** provides a two-way data communication coupling to a network link **719** connected to a local network **721**. For example, the communication interface **717** may be a digital subscriber line (DSL) card or modem, an integrated services digital network (ISDN) card, a cable modem, a telephone modem, or any other communication interface to provide a data communication connection to a corresponding type of communication line. As another example, communication interface **717** may be a local area network (LAN) card (e.g. for Ethernet™ or an Asynchronous Transfer Mode (ATM) network) to provide a data communication connection to a compatible LAN. Wireless links can also be implemented. In any such implementation, communication interface **717** sends and receives electrical, electromagnetic, or optical signals that carry digital data streams representing various types of information. Further, the communication interface **717** can include peripheral interface devices, such as a Universal Serial Bus (USB) interface, a PCMCIA (Personal Computer Memory Card International Association) interface, etc. Although a single communication interface **717** is depicted in FIG. **7**, multiple communication interfaces can also be employed.

The network link **719** typically provides data communication through one or more networks to other data devices. For example, the network link **719** may provide a connection through local network **721** to a host computer **723**, which has connectivity to a network **725** (e.g. a wide area network (WAN) or the global packet data communication network now commonly referred to as the "Internet") or to data equipment operated by a service provider. The local network **721** and the network **725** both use electrical, electromagnetic, or optical signals to convey information and instructions. The signals through the various networks and the signals on the network link **719** and through the communication interface **717**, which communicate digital data with the computer system **700**, are exemplary forms of carrier waves bearing the information and instructions.

The computer system **700** can send messages and receive data, including program code, through the network(s), the network link **719**, and the communication interface **717**. In the Internet example, a server (not shown) might transmit requested code belonging to an application program for implementing an embodiment of the invention through the network **725**, the local network **721** and the communication interface **717**. The processor **703** may execute the transmitted code while being received and/or store the code in the storage device **709**, or other non-volatile storage for later execution. In this manner, the computer system **700** may obtain application code in the form of a carrier wave.

The term "computer-readable medium" as used herein refers to any medium that participates in providing instructions to the processor **703** for execution. Such a medium may take many forms, including but not limited to computer-readable storage medium ((or non-transitory)—e.g., non-volatile media and volatile media), and transmission media. Non-volatile media include, for example, optical or magnetic disks, such as the storage device **709**. Volatile media include dynamic memory, such as main memory **705**. Transmission media include coaxial cables, copper wire and fiber optics, including the wires that comprise the bus **701**. Transmission media can also take the form of acoustic, optical, or electromagnetic waves, such as those generated during radio frequency (RF) and infrared (IR) data communications. Common forms of computer-readable media include, for example, a floppy disk, a flexible disk, hard disk, magnetic tape, any other magnetic medium, a CD-ROM, CDRW, DVD, any other optical medium, punch cards, paper tape, optical mark sheets, any other physical medium with patterns of holes or other optically recognizable indicia, a RAM, a PROM, and

EPROM, a FLASH-EPROM, any other memory chip or cartridge, a carrier wave, or any other medium from which a computer can read.

Various forms of computer-readable media may be involved in providing instructions to a processor for execution. For example, the instructions for carrying out at least part of the embodiments of the invention may initially be borne on a magnetic disk of a remote computer. In such a scenario, the remote computer loads the instructions into main memory and sends the instructions over a telephone line using a modem. A modem of a local computer system receives the data on the telephone line and uses an infrared transmitter to convert the data to an infrared signal and transmit the infrared signal to a portable computing device, such as a personal digital assistant (PDA) or a laptop. An infrared detector on the portable computing device receives the information and instructions borne by the infrared signal and places the data on a bus. The bus conveys the data to main memory, from which a processor retrieves and executes the instructions. The instructions received by main memory can optionally be stored on storage device either before or after execution by processor.

FIG. **8** illustrates a chip set or chip **800** upon which an embodiment of the invention may be implemented. Chip set **800** is programmed to enable detection of an exploit in a network as described herein and includes, for instance, the processor and memory components described with respect to FIG. **8** incorporated in one or more physical packages (e.g., chips). By way of example, a physical package includes an arrangement of one or more materials, components, and/or wires on a structural assembly (e.g., a baseboard) to provide one or more characteristics such as physical strength, conservation of size, and/or limitation of electrical interaction. It is contemplated that in certain embodiments the chip set **800** can be implemented in a single chip. It is further contemplated that in certain embodiments the chip set or chip **800** can be implemented as a single "system on a chip." It is further contemplated that in certain embodiments a separate ASIC would not be used, for example, and that all relevant functions as disclosed herein would be performed by a processor or processors. Chip set or chip **800**, or a portion thereof, constitutes a means for performing one or more steps of enabling detection of an exploit in a network.

In one embodiment, the chip set or chip **800** includes a communication mechanism such as a bus **801** for passing information among the components of the chip set **800**. A processor **803** has connectivity to the bus **801** to execute instructions and process information stored in, for example, a memory **805**. The processor **803** may include one or more processing cores with each core configured to perform independently. A multi-core processor enables multiprocessing within a single physical package. Examples of a multi-core processor include two, four, eight, or greater numbers of processing cores. Alternatively or in addition, the processor **803** may include one or more microprocessors configured in tandem via the bus **801** to enable independent execution of instructions, pipelining, and multithreading. The processor **803** may also be accompanied with one or more specialized components to perform certain processing functions and tasks such as one or more digital signal processors (DSP) **807**, or one or more application-specific integrated circuits (ASIC) **809**. A DSP **807** typically is configured to process real-world signals (e.g., sound) in real time independently of the processor **803**. Similarly, an ASIC **809** can be configured to performed specialized functions not easily performed by a more general purpose processor. Other specialized components to aid in performing the inventive functions described herein may include one or more field programmable gate arrays (FPGA) (not shown), one or more controllers (not shown), or one or more other special-purpose computer chips.

In one embodiment, the chip set or chip **800** includes merely one or more processors and some software and/or firmware supporting and/or relating to and/or for the one or more processors.

The processor **803** and accompanying components have connectivity to the memory **805** via the bus **801**. The memory **805** includes both dynamic memory (e.g., RAM, magnetic disk, writable optical disk, etc.) and static memory (e.g., ROM, CD-ROM, etc.) for storing executable instructions that when executed perform the inventive steps described herein to enable detection of an exploit in a network. The memory **805** also stores the data associated with or generated by the execution of the inventive steps.

While certain exemplary embodiments and implementations have been described herein, other embodiments and modifications will be apparent from this description. Accordingly, the invention is not limited to such embodiments, but rather to the broader scope of the presented claims and various obvious modifications and equivalent arrangements.

What is claimed is:

1. A method comprising:

determining, by a processor, a logical configuration of a network comprising a plurality of links connecting a plurality of nodes;

determining, by the processor, a physical path corresponding to one of the links, the physical path including a plurality of network switches of the network, wherein the processor is configured to determine whether data sent on one of the nodes to another one of the nodes via the one link is received at the other node;

receiving an error detection value computed by one of the network switches using either data stored in one or more routing tables of the one network switch, a configuration type of the one network switch, or a combination thereof; and

validating, by the processor, the one network switch as secured from one or more exploits of the network by determining that the error detection value is identical to a value inaccessible to the one network switch.

2. The method according to claim **1**, comprising:

receiving another error detection value computed by another one of the network switches;

determining, by the processor, whether the other error detection value corresponds with another value, the other value being inaccessible to the one network switch and the other network switch;

subsequently validating, by the processor, the other network switch as secured from the one or more exploits by determining that the other error detection value is identical to the other value;

receiving a first and second geolocation from the one network switch and the other network switch switches, respectively; and

determining, by the processor, a physical path of network traffic forwarded by the one network switch, other network switch, or a combination thereof based on the received first and second geolocations when the one network switch and the other network switch are validated.

3. The method according to claim **2**, comprising:

determining, by the processor, an indication of a physical location associated with the network traffic; and

comparing the indication of the physical location with the determined physical path.

4. The method according to claim **3**, comprising:

determining a source and/or destination address of a datagram of the network traffic; and

determining the indication of the physical location according to the source and/or destination address.

5. The method according to claim **4**, further comprising:

determining whether the first network switch connects an end device associated with the destination or source address to the network switches of the network; and

determining the indication of the physical location as the first geolocation based on whether the first network switch connects the end device to the network switches.

6. The method according to claim **3**, wherein the indication of the physical location is an automatic number identification (ANI) of the network traffic, and

wherein the error detection value includes a checksum.

7. The method according to claim **3**, comprising:

determining a media access control (MAC) address of an endpoint device connected to the network via the first network switch, the endpoint device being an endpoint of the network traffic;

determining a type of device according to the MAC address; and

determining the indication of the physical location based on the type of device.

8. The method according to claim **1**, wherein the value is stored in a datastore inaccessible to the processor and/or calculated by another processor, and the data is a datagram, the method further comprising:

when the error detection value does not match with the value inaccessible to the one network switch, initiating a stateful inspection of the network to determine the one or more exploits of the network that cause the mismatch.

9. An apparatus comprising:

at least one processor; and

at least one memory including computer program code for one or more programs,

the at least one memory and the computer program code configured to, with the at least one processor, cause the apparatus to perform at least the following,

determine a logical configuration of a network comprising a plurality of links connecting a plurality of nodes;

determine a physical path corresponding to one of the links, the physical path including a plurality of network switches of the network, wherein the processor is configured to determine whether data sent on one of the nodes to another one of the nodes via the one link is received at the other node;

receive an error detection value computed by a first network switch of the network switches using either data stored in one or more routing tables of the first network switch, a configuration type of the first network switch, or a combination thereof; and

validate the first network switch as secured from one or more exploits of the network by determining that the error detection value is identical to a value inaccessible to the first network switch.

10. The apparatus according to claim **9**, wherein the apparatus is further caused to:

receive a second error detection value computed by a second network switch of the network switches;

compare, the second error detection value with a second value, the first and second values being inaccessible to the first and second network switches;

subsequently validate the second switch as secured from the one or more exploits by determining that the second error detection value is identical to the second value;

receive a first and second geolocation from the first and second network switches, respectively; and

determine a physical path of network traffic forwarded by the first network switch, the second network switch, or a combination thereof based on the received first and second geolocations when the first and second network switches are validated.

11. The apparatus according to claim **10**, wherein the apparatus is further caused to:

determine, an indication of a physical location associated with the network traffic; and

compare the indication of the physical location with the determined physical path.

12. The apparatus according to claim **11**, wherein the apparatus is further caused to:

determining a source and/or destination address of a datagram of the network traffic; and

determining the indication of the physical location according to the source and/or destination address.

13. The apparatus according to claim **12**, wherein the apparatus is further caused to:

determining whether the first network switch connects an end device associated with the destination or source address with the network switches of the network; and

determining the indication of the physical location as the first geolocation based on whether the first network switch connects the end device to the network switches.

14. The apparatus according to claim **11**, wherein the indication of the physical location is an automatic number identification (ANI) of the network traffic.

15. The apparatus according to claim **11**, wherein the apparatus is further caused to:

determine a media access control (MAC) address of a endpoint device connected to the network via the first network switch, the endpoint device being an endpoint of the network traffic;

determine a type of device according to the MAC address; and

determine the indication of the physical location based on the type of device.

16. The apparatus according to claim **9**, wherein the first error detection value is according to a configuration type and/or a datastore associated with the first network switch, the value is stored in a datastore inaccessible to the apparatus and/or calculated by another apparatus and the data is a datagram, the apparatus being further caused to initiate a stateful inspection of the network based on the comparison.

17. A method comprising:

receiving, at a network switch, network traffic comprising datagrams;

determining, by the network switch, a header of one of the datagrams, the header indicating a destination address;

selecting, by the network switch, a physical link to transport the one datagram based on the destination address;

determining, by the network switch, a network node to forward the one datagram based on the destination address;

forwarding, by the network switch, the one datagram to the network node on the physical link;

computing, at the network switch, an error detection value for the network switch using either data stored in one or more routing tables of the network switch, a configuration type of the network switch, or a combination thereof; and

forwarding the error detection value to a processing device to validate the network switch as secured from one or more exploits of the network by determining that determine whether the error detection value is identical corresponds to a value inaccessible to the network switch.

18. The method according to claim **17**, further comprising:

determining the network node according to the routing table of the network switch, wherein the error detection value is computed based on values indicated in the routing table.

19. An apparatus comprising:

at least one processor; and

at least one memory including computer program code for one or more programs,

the at least one memory and the computer program code configured to, with the at least one processor, cause the apparatus embedded in a network switch to perform at least the following,

receive network traffic comprising datagrams;

determine a header of one of the datagrams, the header indicating a destination address;

select a physical link to transport the one datagram based on the destination address;

determine a network node to forward the one datagram based on the destination address;

forward the one datagram to the network node on the physical link;

compute an error detection value for the network switch using either data stored in one or more routing tables of the network switch, a configuration type of the network switch, or a combination thereof; and

forward the error detection value to a processing device to validate the network switch as secured from one or more exploits of the network by determining that the error detection value is identical to a value inaccessible to the network switch.

20. The apparatus according to claim **19**, wherein the apparatus is further caused to:

determining the network node according to the routing table of the network switch, wherein the error detection value is computed based on values indicated in the routing table.

21. The method according to claim **1**, wherein the one or more exploits of the network include spoofing of one or more internet protocol addresses, spoofing of one or more media access control addresses, spoofing of one or more automatic number identifications, or a combination thereof, associated with the physical path.

22. The method according to claim **1**, further comprising:

when the error detection value does not match with the value inaccessible to the one network switch, determining the one or more exploits of the network that cause the mismatch by auditing the one network switch, the physical path, a logical route corresponding to the physical path, a portion of the network including the physical path, or a combination thereof.

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